

Chemistry 1500: Chemistry in Modern Living

Topic 5: The Fires of Nuclear Fission

Atomic Structure, Nuclear Fission and Fusion, and Nuclear Weapons

Chemistry in Context, 2nd Edition: Chapter 8, Pages 245-280

Chemistry in Context, 3rd Edition: Chapter 7, Pages 265-304

Chemistry in Context, 4th Edition: Chapter xxx, Pages xxx-xxx

The Figure, Table, & Problem numbers in these notes are taken from the 4th edition of the text unless otherwise noted.

Graphics from Text: Figure xxx.0

Outline

5A	ATOMIC AND NUCLEAR STRUCTURE	3
5B	FISSION AND FUSION	5
5C	NUCLEAR REACTIONS AND CHAIN REACTIONS	6
5D	NUCLEAR FISSION REACTORS	7
5E	RADIATION AND RADIOACTIVE DECAY	10
5F	NUCLEAR POWER AND THE WORLD	12
5G	NUCLEAR BOMB DESIGN	13

5A Atomic and Nuclear Structure

- Atomic Structure:
 - Nucleus
 - Electron Cloud

- Nuclear Structure:
 - Neutrons and Protons
 - Strong Nuclear Force vs. Electrostatic Force
 - Rubber Baggie Model

- Isotopes
 - Atomic Number
 - Determined by number of protons
 - Mass Number
 - Equals the total number of protons and neutrons

➤ Ask Students: Give the number of protons and the number of neutrons for each of the following isotopes or give the atomic symbol, as required

➤ Group Activity



➤ 32 protons and 37 neutrons ⇒

➤ 17 protons and 16 neutrons ⇒



5B Fission and Fusion

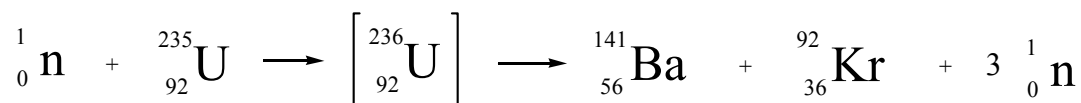
- **Fission Reactions** are nuclear reactions that split the nucleus into smaller fragments

- **Fusion Reactions** are nuclear reactions that join two units to form a larger nucleus

- These nuclear reactions can be extremely exothermic
 - They produce large amounts of heat
 - For example ^{235}U fission \Rightarrow energy equivalent to 33,000 tons of TNT from 1 kg of Uranium
 - This energy is produced via the conversion of mass to energy
 - Einstein $\Rightarrow E = m c^2$

5C Nuclear Reactions and Chain Reactions

- Involve the **splitting or combining of nuclei** and fragments
- They can be balanced much like chemical reactions



➤ Chain Reactions

- Graphics from Text: Figure 8.3 in 2nd Edition and 7.2 in 3rd

Edition, Chain Reaction Diagram

- Average of 2 to 3 **neutrons per fission**

- **Induced nuclear fission**

5D Nuclear Fission Reactors

- Graphics from Text: Figure 7.3 in 3rd Edition, Diagram of a nuclear power plant

- Roles of Major Components
 - Fuel Rods

 - Moderator (Thermal Neutrons)

 - Control Rods

 - Steam system
 - Piping
 - Turbines
 - Cooling towers / heat exchangers

- Graphics from Text: Figure 7.4 in 3rd Edition, Diagram of fuel assembly in nuclear power plant

- Comparison of various reactor types
 - Key variables
 - Level of enrichment
 - Moderator type
 - Cooling fluid
 - Pressurized light water reactor
 - US Navy
 - Heavy water reactor, CANDU
 - Liquid metal cooled reactor
 - Graphite moderated / Helium Cooled reactor
 - Natural Reactors

- What prevents melt downs
 - Active control systems
 - Redundancy
 - Mechanical errors
 - Brittle piping (alloys), Welding, Pumps
 - Human errors
 - Homer Simpson
 - Passive control systems
 - Energy density
 - No-maintenance piles
- What happened at Chernobyl
- Breeder Reactors



5E Radiation and Radioactive Decay

- Graphics from Text: Table 8.1 in 2nd Edition and 7.1 in 3rd Edition, Radioactive emissions

- Types of Radiation
 - Alpha particles, Helium nuclei
 - Beta particles, electrons
 - Gamma rays, high energy photons
 - Neutrons

- Variations in penetrating power

- Doses
 - Lethal vs. typical
 - The controversy about low doses

- Graphics from Text: Table 8.4 in 2nd Edition and Figure 7.10 in 3rd Edition, US Background Radiation Sources

➤ Radioactive Decay

➤ Half life of an isotope for spontaneous decay

➤ Ranges of half lives in common isotopes

➤ Graphics from Text: Figure 8.9 in 2nd Edition and 7.12 in 3rd

Edition: Radioactive decay curve for ^{239}Pu

5F Nuclear Power and the World

- Graphics from Text: Table 8.5 from 2nd Edition and Table 7.4 from 3rd Edition, Nuclear Power Statistics for Selected Countries

- Graphics from Text: Figure 8.10 from 2nd Edition and Figure 7.19 from 3rd Edition, Percentage of Electrical Power Generated from Nuclear Reactors for Selected Countries

- Ask Students: Develop some reasons why the differences between different countries
 - Group Activity

5G Nuclear Bomb Design

➤ Critical Mass

➤ 15 to 18 kg of ^{235}U

➤ Crude Fission bomb design

➤ Tube cannon

➤ Collapsing shell

➤ Crude Fusion bomb design

➤ Miniaturization of bombs

Index of Vocabulary and Major Topics

2		
²³⁵ U	.....5, 13	
²³⁹ Pu	.....11	
A		
Active control systems	.....9	
Alpha particles	.....10	
Ask Students	.....4, 12	
Atomic and Nuclear Structure	.....3	
Atomic Number	.....3	
Atomic Structure	.....3	
atomic symbol	.....4	
B		
Beta particles	.....10	
Breeder Reactors	.....9	
C		
CANDU	.....8	
Chain Reaction Diagram	.....6	
Chain Reactions	.....6	
Chernobyl	.....9	
Control Rods	.....7	
Cooling fluid	.....8	
Cooling towers	.....7	
Critical Mass	.....13	
D		
Doses	.....10	
E		
$E = m c^2$	.....5	
Einstein	.....5	
Electron Cloud	.....3	
electrons	.....10	
Electrostatic Force	.....3	
Energy density	.....9	
enrichment	.....8	
exothermic	.....5	
F		
fission	.....5	
Fission and Fusion	.....5	
Fission bomb design	.....13	
Fission Reactions	.....5	
fuel assembly in nuclear power plant	.....7	
Fuel Rods	.....7	
Fusion bomb design	.....13	
Fusion Reactions	.....5	
G		
Gamma rays	.....10	
Graphics from Text	.....6, 7, 10, 11, 12	
Graphite moderated / Helium Cooled reactor	.....8	
Group Activity	.....4, 12	
H		
Half life	.....11	
heat exchangers	.....7	
Heavy water reactor	.....8	
Helium nuclei	.....10	
Homer Simpson	.....9	
I		
Induced nuclear fission	.....6	
isotope	.....11	
isotopes	.....4	
Isotopes	.....3	
L		
Liquid metal cooled reactor	.....8	
low doses	.....10	
M		
Major Components	.....7	
Mass Number	.....3	
mass to energy	.....5	
melt downs	.....9	
Moderator	.....7, 8	
N		
Natural Reactors	.....8	
Neutrons	.....3, 10	
neutrons per fission	.....6	
Nuclear Bomb Design	.....13	
Nuclear Fission Reactors	.....7	
Nuclear Power and the World	.....12	
nuclear power plant	.....7	
Nuclear Power Statistics for Selected Countries	.....12	
nuclear reactions	.....5	
Nuclear Reactions and Chain Reactions	.....6	
Nuclear Structure	.....3	
nucleus	.....5	
Nucleus	.....3	
number of neutrons	.....4	
number of proton	.....4	

P

Passive control systems	9
penetrating power	10
Percentage of Electrical Power Generated from Nuclear Reactors.....	12
photons	10
Piping.....	7
Pressurized light water reactor.....	8
Protons.....	3

R

Radiation.....	10
Radiation and Radioactive Decay.....	10
Radioactive Decay	11
Radioactive decay curve.....	11
Radioactive emissions	10

reactor types.....	8
Redundancy	9
Rubber Baggie Model.....	3

S

splitting or combining of nuclei.....	6
Steam system	7
Strong Nuclear Force.....	3

T

Thermal Neutrons	7
TNT	5
Turbines.....	7

U

US Background Radiation Sources	10
---------------------------------------	----